AFRL-VA-WP-TP-2004-314

AUTOMATED AERIAL REFUEL (AAR) TECHNOLOGIES AND CHALLENGES

Delivery Order 0048

David R. Riley

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775 East Marginal Way
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APRIL 2004

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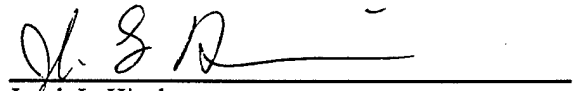

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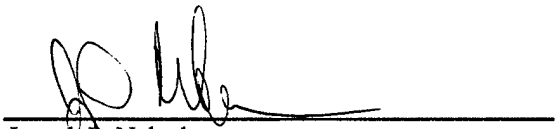
AFRL/Control Sciences Division



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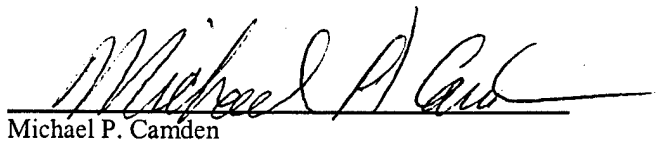

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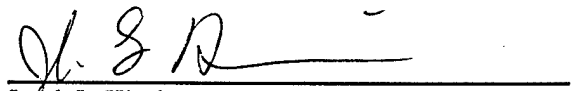

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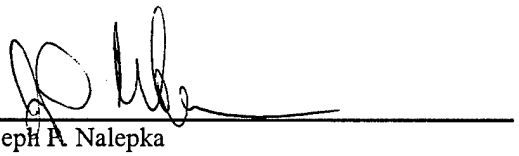

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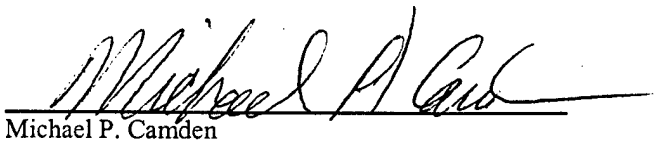

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This paper talks about the challenges of Aerial Refueling of Unmanned Air Vehicles.

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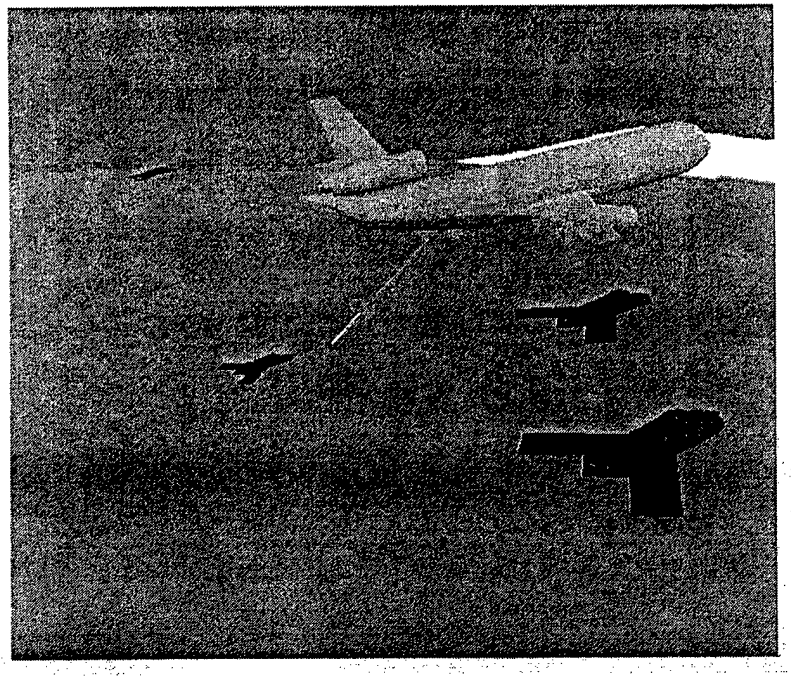
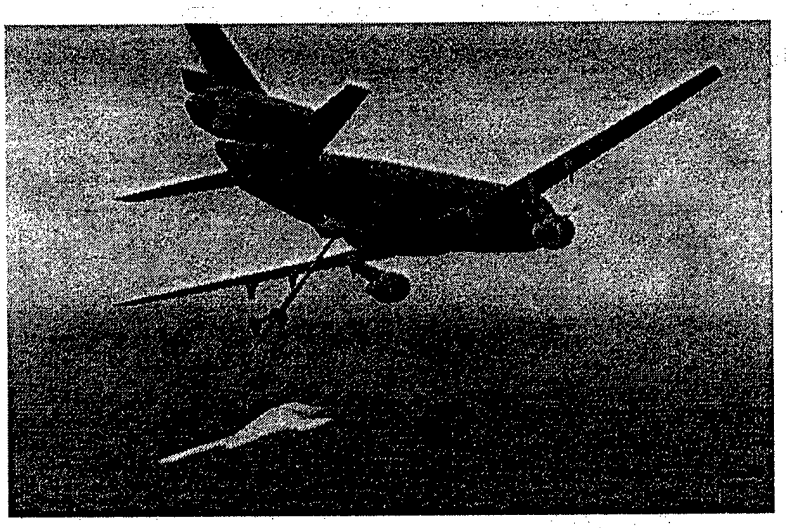
Automated Aerial Refuel (AAR) Technologies and Challenges

AIAA Section Meeting
13 Apr 04



Video Courtesy Bihrle Applied Research



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Presentation Outline

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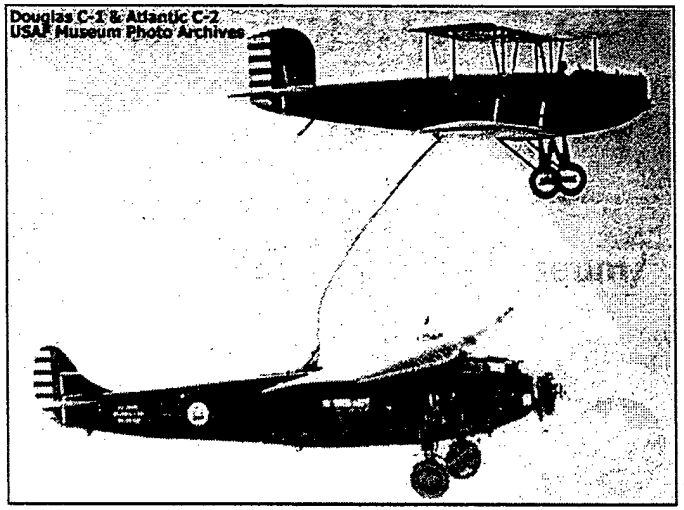
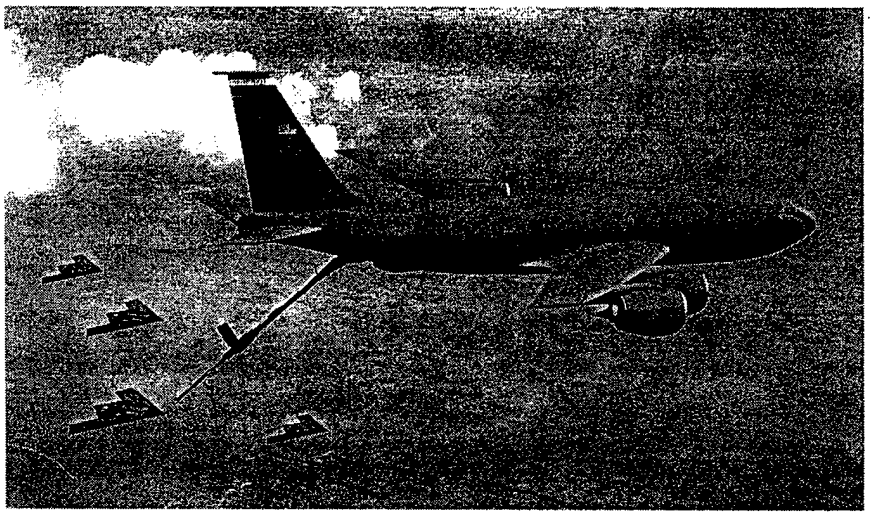


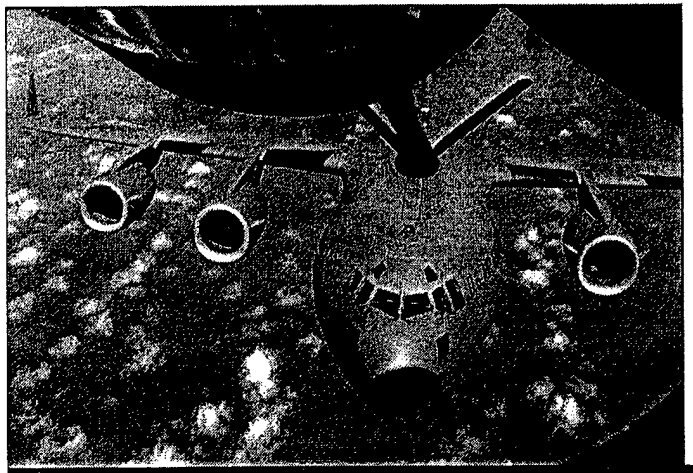
- Background
  - Significance to Air Force
  - AAR Program Key Aspects
  - AAR Project Approach
  - National AAR Team
- Conceptual Design Development Process
  - AAR Process
  - CONOPs and Requirements
- Conceptual Designs
  - Selection Process
  - Conceptual Design Families
- Simulation Development
- AAR's Future



Significance to Air Force

- Unmanned Aerial Vehicles
  - Extends Range
  - Shortens Response for Time-Critical Targets
  - Maintains In-Theater Presence Using Fewer Assets
  - Deployment with Manned Fighters and Attack Without the Need of Forward Staging Areas

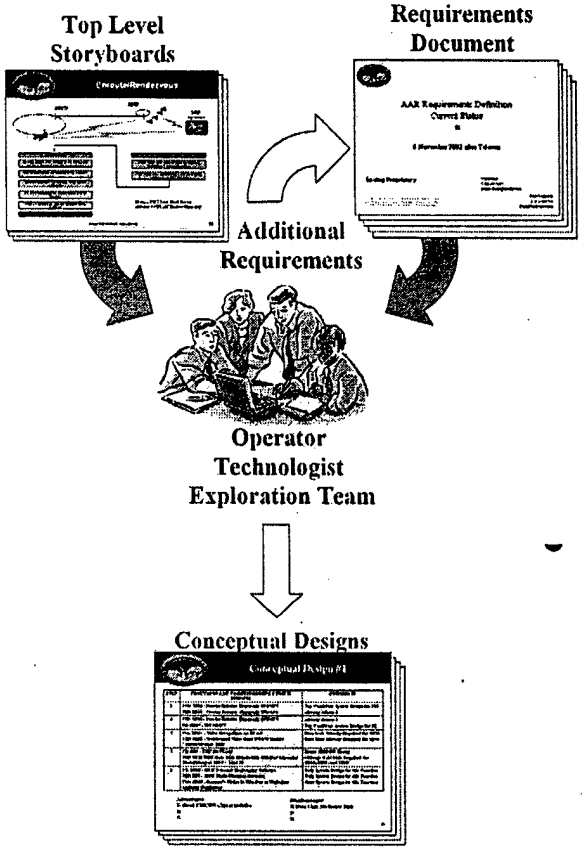
"If we decided to fly them across the ocean, we have to work on things like automatic air refueling" -Gen. John Jumper, USAF, August 2001



- **Manned Aircraft**
  - **Provides Adverse Weather Operations**
  - **Improves Fueling Efficiency**
  - **Reduces Pilot Workload**

AAR Assists J-UCAS in Reaching its Full Potential and Greatly Enhances Manned Refueling

AAR Program Key Aspects

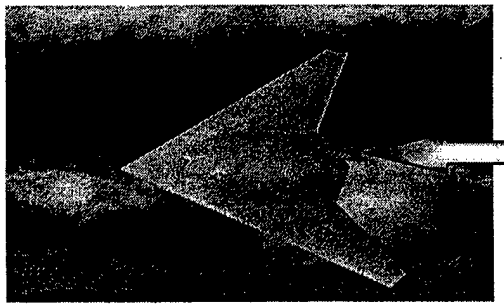


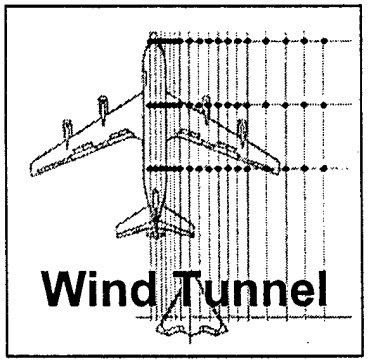
- Automating the Receiver
  - Demonstrate an Operationally Feasible UAV Refueling Capability
- Near-Term Focus – Boom/Receptacle Refueling
  - Target was Air Force UAVs
  - Near-Term Refueling

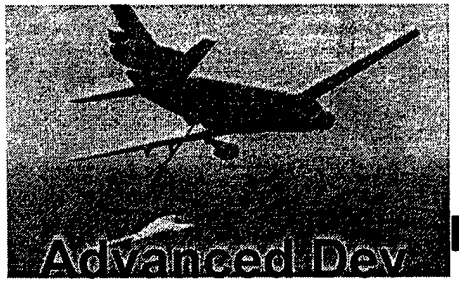
Top Down, Work Right Spiral Approach to Provide Timely Technology Transition

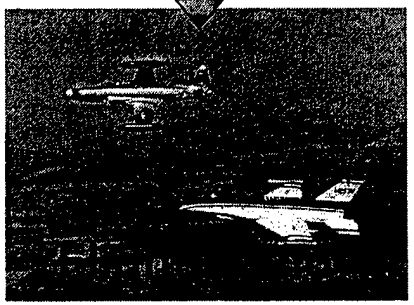
AAR Project Approach

Heavy User Involvement From AMC/XPR, ACC/DRZ, ASC/FB, And DARPA

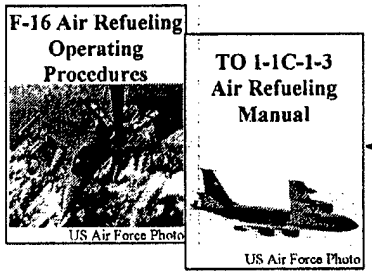


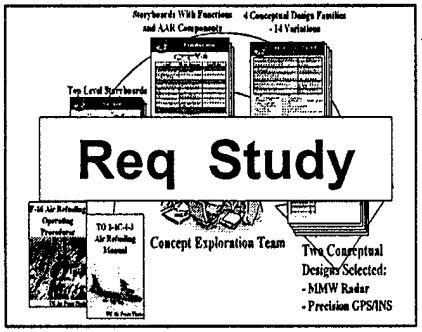




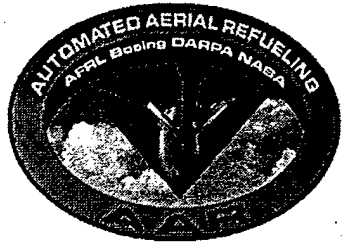


Operational Concepts





Direct User and SPO Involvement Facilitates Transition Into Operational System



National AAR Team

ACC/DR

ASC/FB
ASC/GR

AFRL/VA
AFRL/HE
AFRL/SN
AFRL/MN
AIR FORCE RESEARCH LABORATORY

DARPA

AMC/XP

NASA

Navy

GENERAL DYNAMICS
Advanced Information Systems

NORTHROP GRUMMAN
Electronic Systems

BOEING

SynGenics Corporation

Bihrle
APPLIED RESEARCH INC

Conceptual Design Development Process

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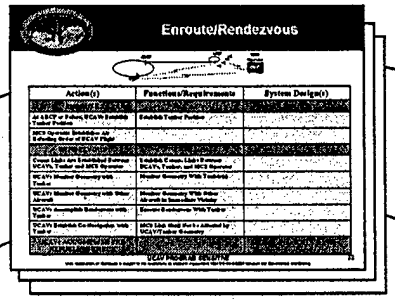
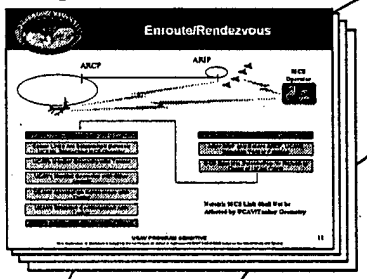
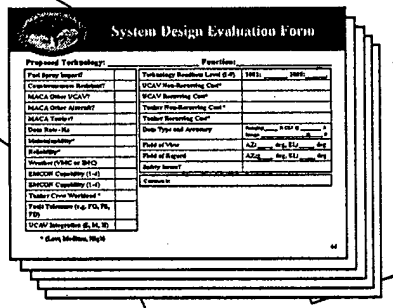
Storyboards With Functions and AAR Components



Top Level Storyboards

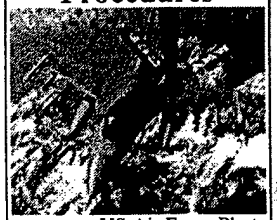


AAR Components Evaluation



Operational Concepts

F-16 Air Refueling Operating Procedures



US Air Force Photo

TO 1-1C-1-3 Air Refueling Manual

US Air Force Photo

Concept Exploration Team

Conceptual Designs
- **Navigation Based**
- **Sensor Based**

J-UCAS Mission/AAR Overview

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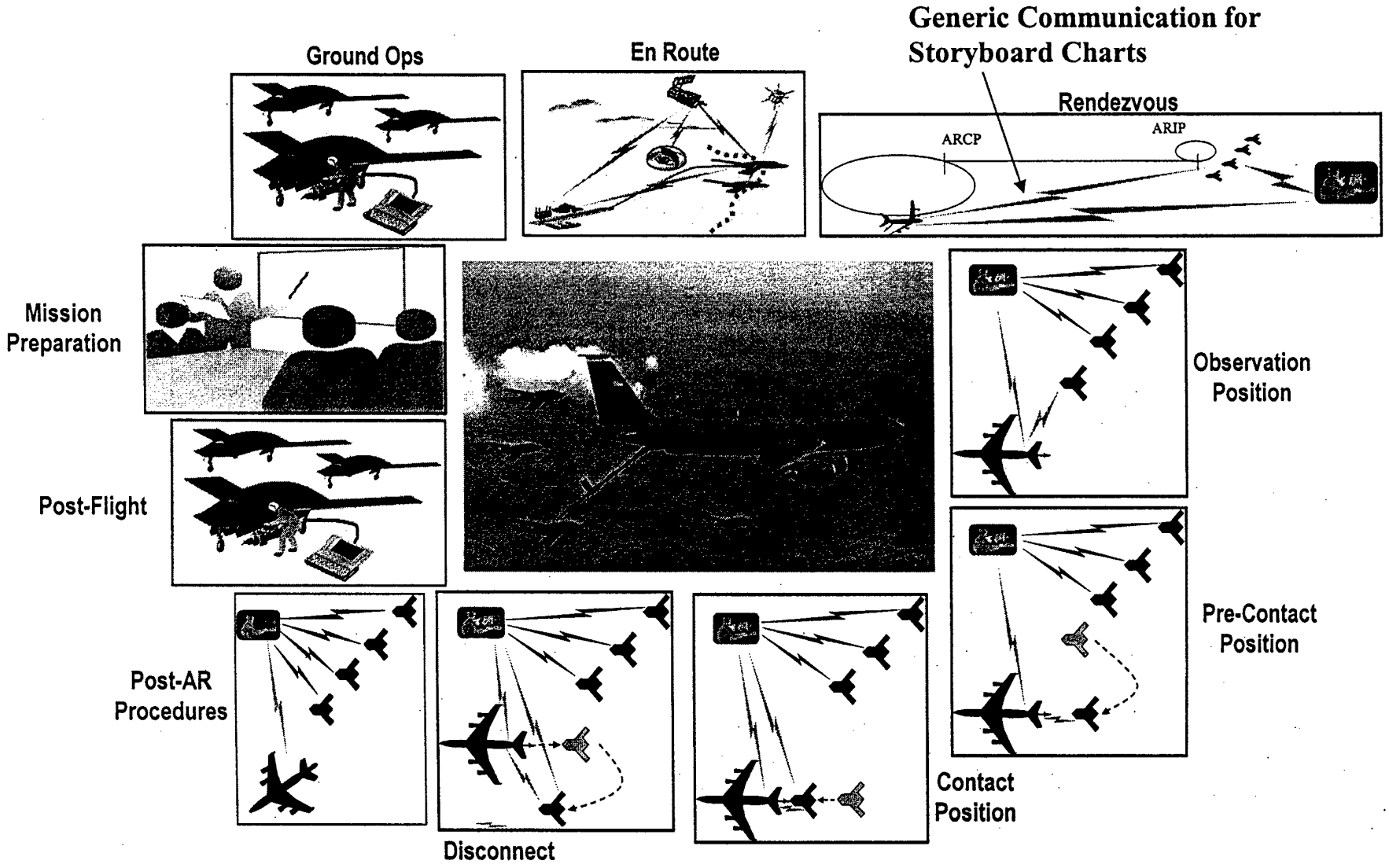
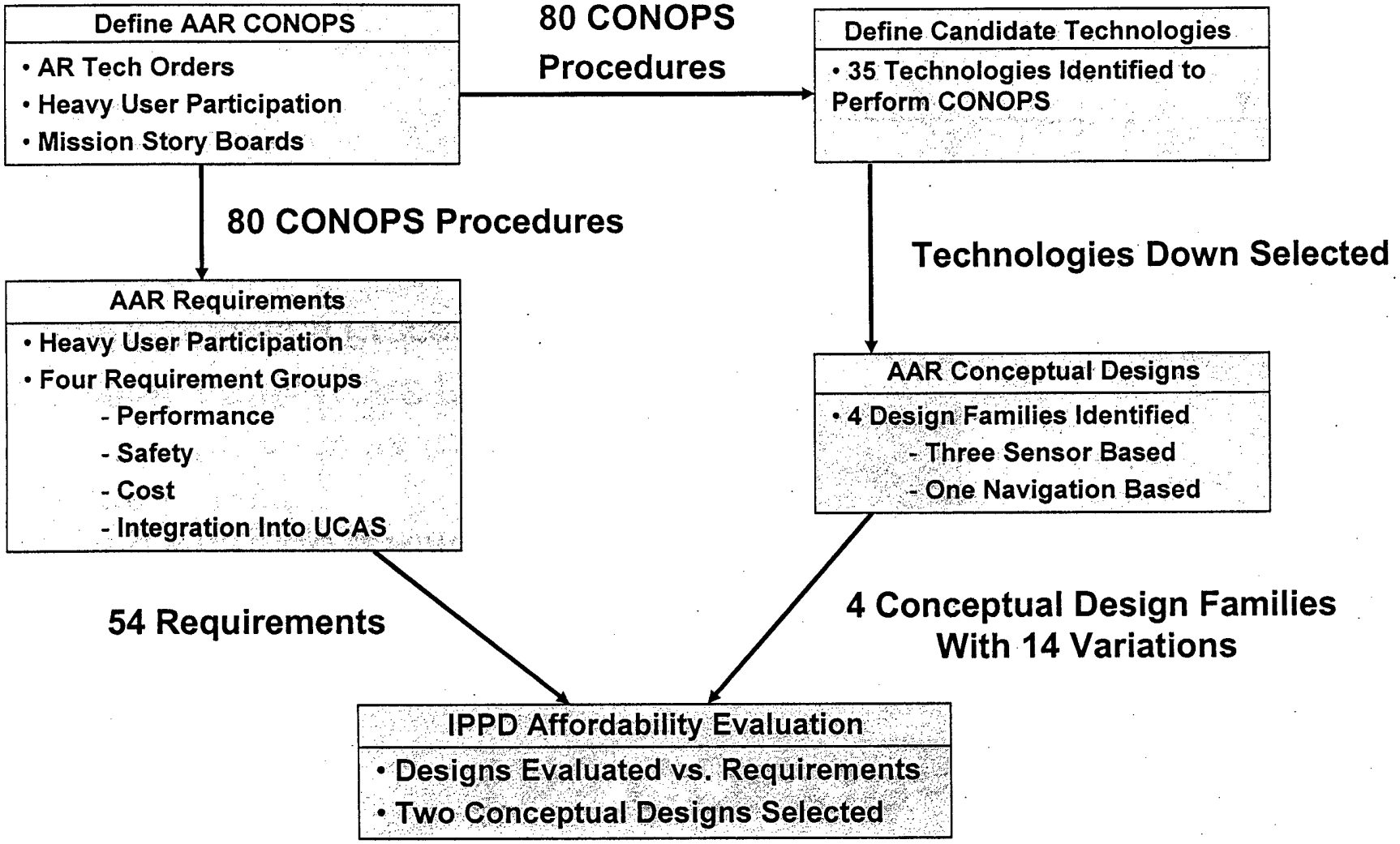
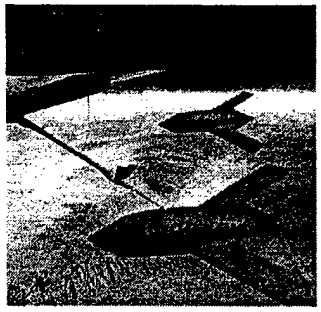


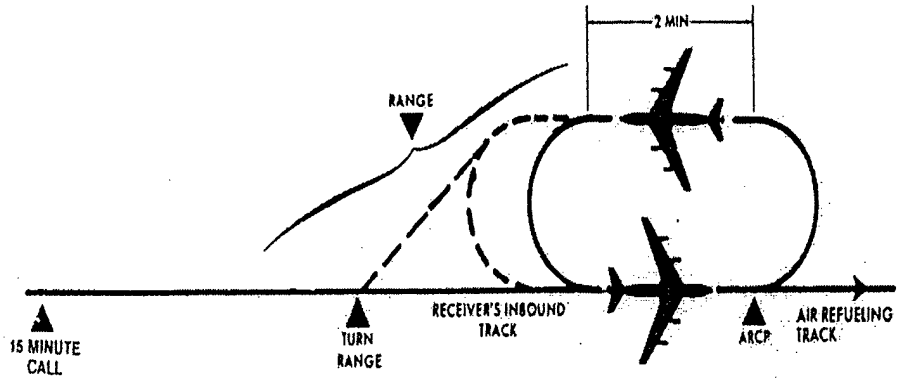
The AAR Process



The CONOPs

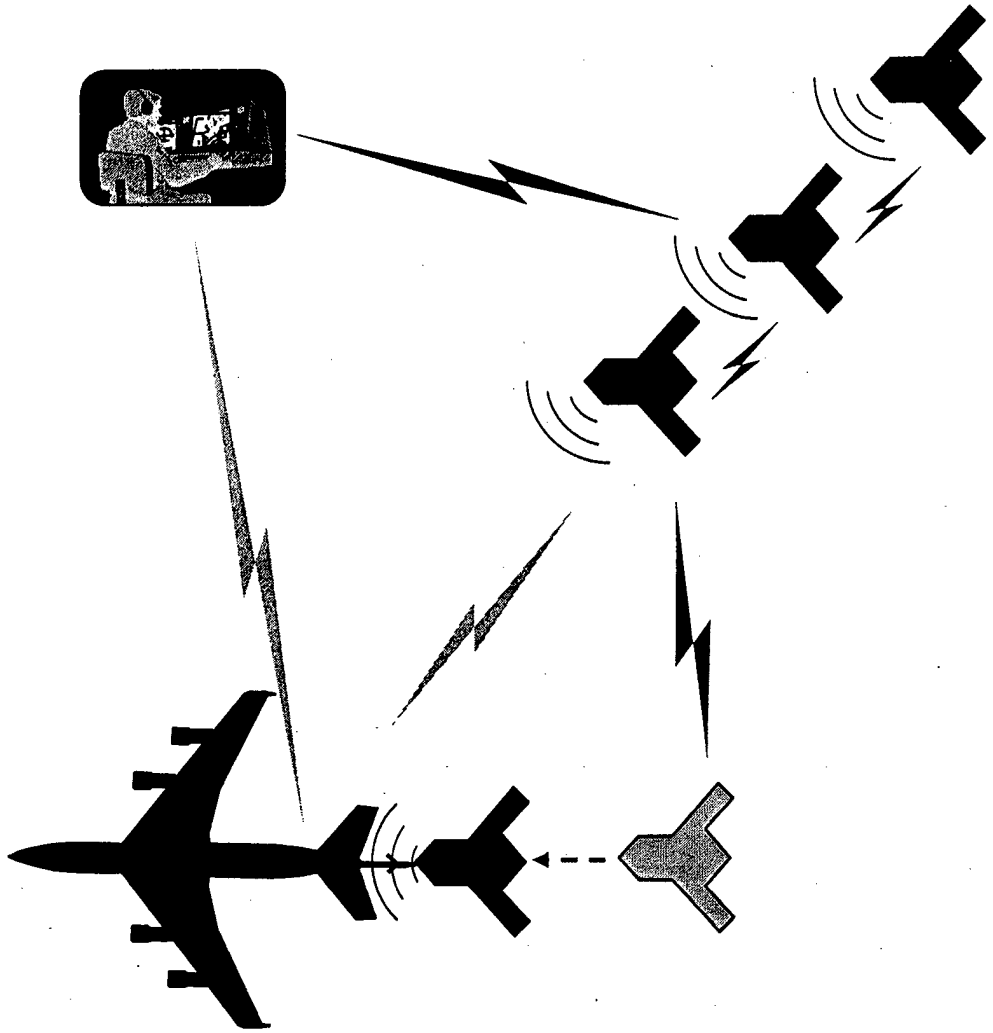
- Working with ACC & AMC to Develop Conops
- Used F-16 Procedures As Baseline
- Refueling 4-Ship UCAS Packages
- Manned Refueling Procedures





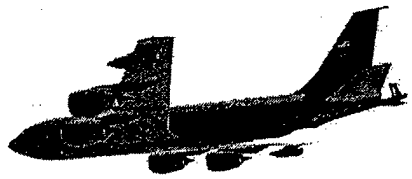
Based AAR Procedures On Current Manned Aircraft Procedure Ensuring Seamless Integration, Ease Transition

Example CONOPs:
Contact Position



Authorized UCAS Stabilizes in Pre-Contact Position
Boomer Authorizes UCAS to Contact Position
Authorized UCAS Stabilizes in Contact Position
Boomer Plugs UCAS
UCAS Acknowledges Contact to MCS Operator
Confirmation of Contact Is Provided to Tanker
UCAS Maintains Contact Position
UCAS Takes Fuel

Overarching User Requirements

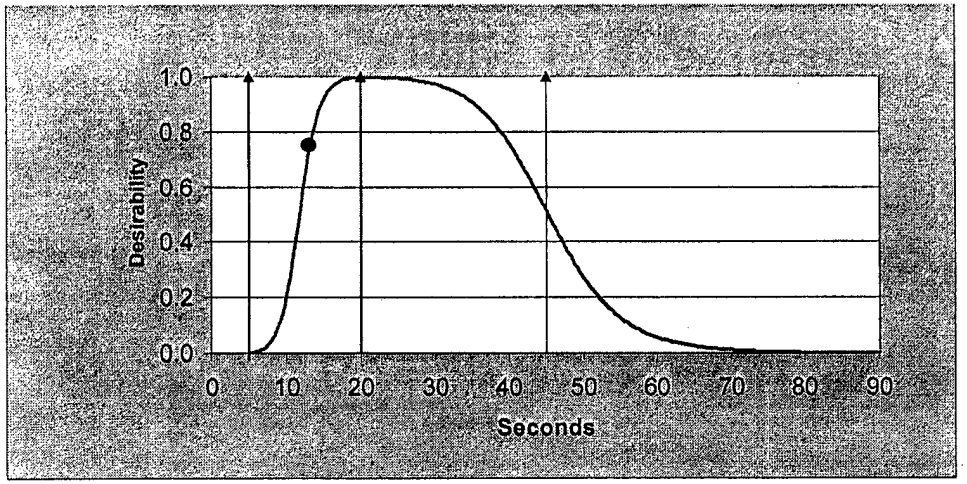


- User Relevance Requires:
  - **Protect Tanker From Collision With UCASs**
  - **Identify and Design Most Affordable Solution**
    - **Consider Impact to Rest of UCAS System of Systems (SoS) Impact**
    - **Minimal Impact to LO Design**
    - **Minimize (or Eliminate) Tanker Modifications**
  - **Minimize Impact to Refueling Mixed Fleet Operation**

AAR Requirements: Performance Example

P001B: Refueling Efficiency: Closure to Contact

- **UCAV will move smoothly and efficiently from the Precontact Position to the Contact Position upon Boomer authorization.**

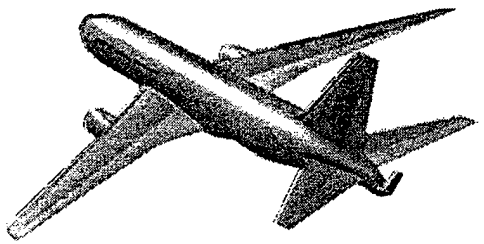


Time (seconds) from Boomer authorization (to close to contact) until receiver stabilizes in Contact Position. Threshold is the typical time for piloted aircraft.

- 4 Areas
  - –Performance
  - –Safety
  - –Cost
  - –Integration
- 54 Requirements
- Developed With Direct Warfighter Involvement
- Derived from Battlefield Requirements and CONOPs

Critical Functions Drive AAR Conceptual Design Selection

- **Strongest Design Drivers Functions (In Order of Priority):**
  - **UCAS Ability to Precisely Maneuver Around Tanker**
  - **UCAS Ability to Perform Rendezvous with Tanker**
- **Other Important Functions**
  - **Boomer Ability to Immediately Command Break-Away**
  - **Tanker's Ability to Determine Range to UCAS in Real Time (Point Parallel Rendezvous)**
  - **Tanker's Ability to Communicate with MCS Operator**



Precision Positioning System Accuracy Requirements at Contact

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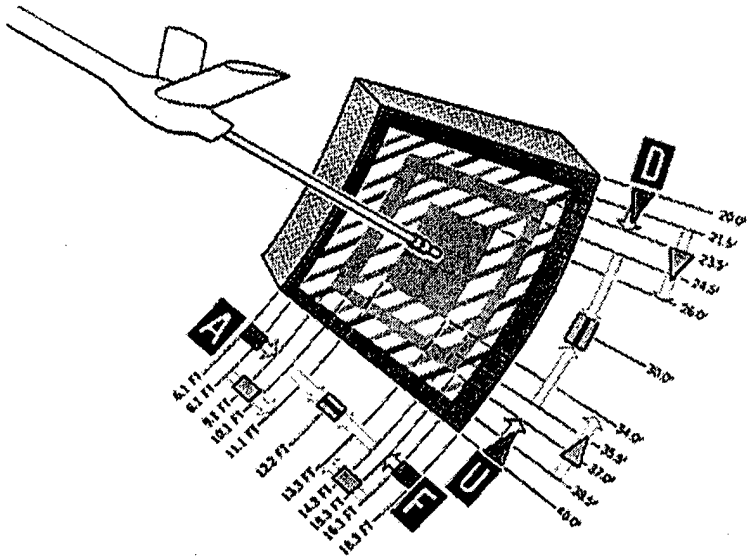
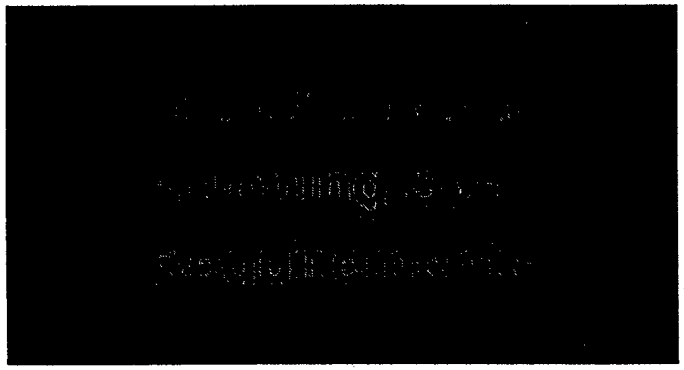
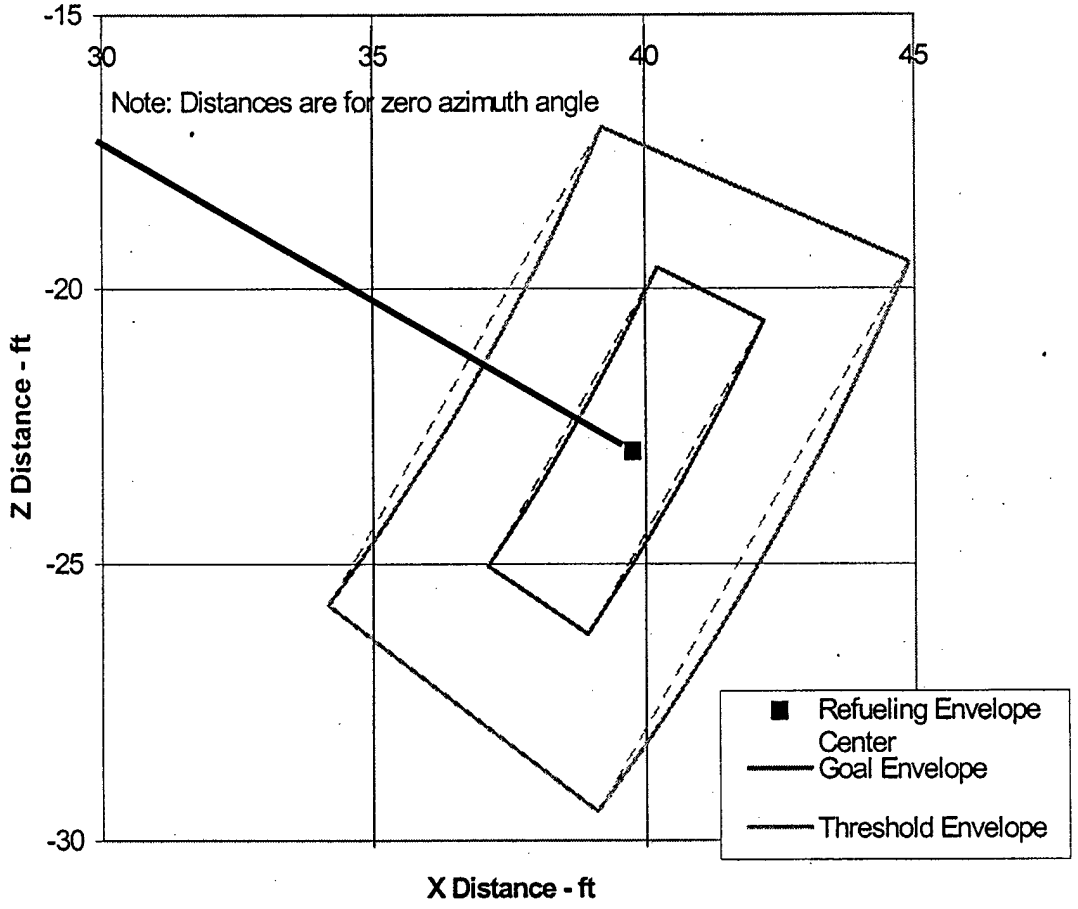
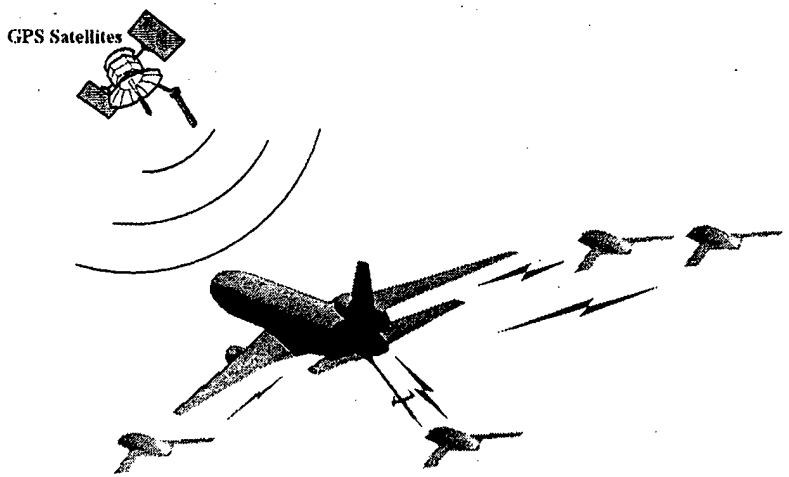




Boom Air-to-Air Refueling Envelope



AAR Conceptual Design Families



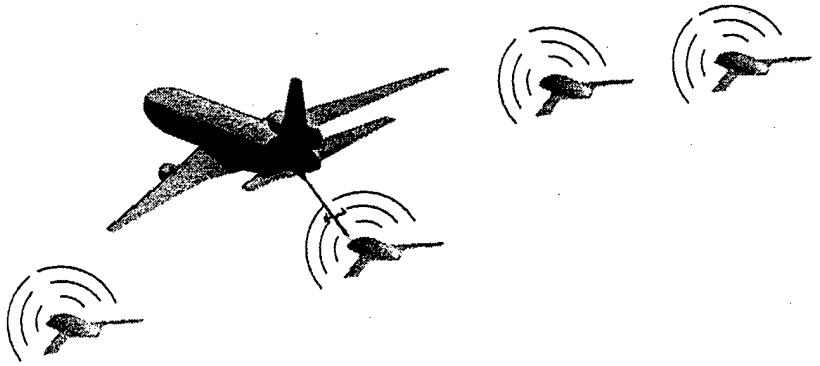
Navigation-Based

Advantages:

- **Lowest Technical Risk For Initial Capability**
- **All Weather Capability**
- **Compatible With Navy Ops**
- **Simple Vehicle Integration**

Disadvantages:

- **Requires Tanker Modifications**



Sensor Based

Advantages:

- **Most Affordable Conceptual Design**
- **Sensor May Enable Additional UCAS Capabilities**

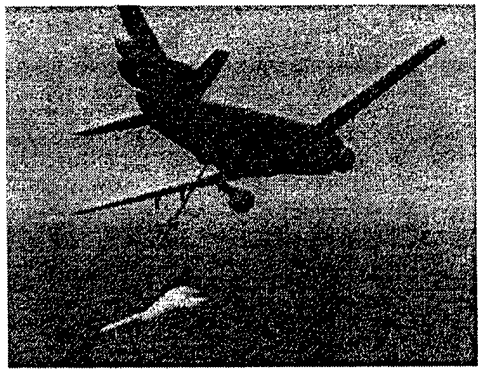
Disadvantages:

- **UCAS Vehicle Integration**
- **Sensor Development Risk**

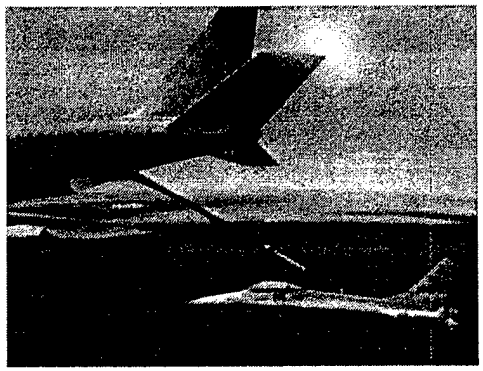
Simulation Development

- Integrated Aerial Refueling R&D Simulation Being Developed
  - Boomer Station
  - UCAS Operator Station
  - Tanker Pilot Cube
  - Other Receiver Stations
- Provides Test Bed for AAR System Development
  - Allows Rapid Prototyping and Early Operator Interactions
  - Helps Develop and Visualize Correct Story Boards

PC Based Simulation



Infinity Cube Simulation



Early Operator Interaction with the AA

Summary

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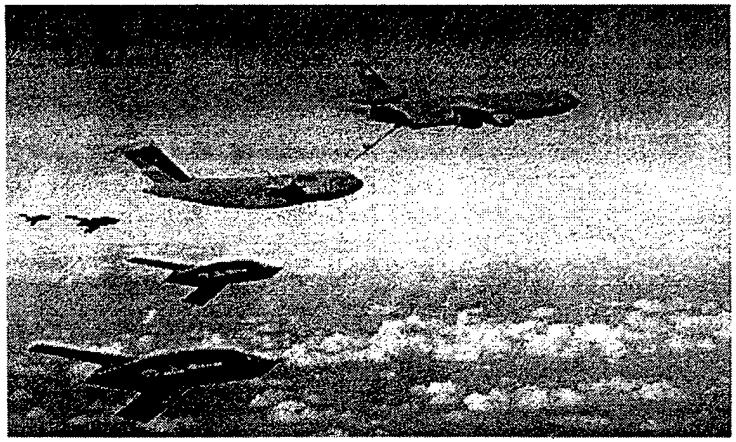
- Automated Refueling Is a Key Capability for UCAS
- Automation Can Provide Significant Improvements in Refueling Capability and Efficiency
- Technology Application to Manned Aircraft
  - Automatic Adverse Weather Rendezvous
  - Situational Awareness and Collision Avoidance for Simultaneous Multiple Receivers
- AFRL, ASC, AMC, ACC, and DARPA have Teamed With Industry
- Concepts Developed in Desktop Simulation Environment can be Quickly Moved to a Man-In-The-Loop Simulation Environment for Boomer, Tanker Pilot, and UAV Controller Evaluations



AAR's Future

PHANTOM WORKS™

- **Continue Requirements Development**
  - Analysis
  - Simulation
    - Off-Line Simulations
    - Real Time "Boomer in the Loop"
- **AAR Technology Maturation**
  - Flight Test
    - Gather Sensor Data
    - Demonstrate Station Keeping Capability
    - Demonstrate Dry/Wet Hookups
      - Boom and Receptacle
      - Probe and Drogue